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MINING AND MILLING METHODS AND COSTS AT THE BLACK HILLS TIN CO., TINTON, S. DAK.

BY

JOS. R. GUITERAS

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MINING AND MILLING METHODS AND COSTS AT THE BLACK HILLS TIN CO., TINTON, S. DAK.[1]

By Jos. R. Guiteras[2]

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[1] The Bureau of Mines will welcome reprinting of this paper provided the following footnote acknowledgment is used: "Reprinted from Bureau of Mines Information Circular 7084."

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INTRODUCTION

This paper is one of a series describing mining and milling methods and costs being published by the Bureau of Mines. It deals with the mineral resources of western South Dakota and describes the mining and milling of tantalite and associated amblygonite by the Black Hills Tin Co. and the Fansteel Mining Corporation.

ACKNOWLEDGMENTS

Acknowledgment is made to Earl C. Schultz and Arthur I. Johnson, respectively superintendent and engineer for both the Black Hills Tin Co. and the Fansteel Mining Corporation, who contributed the information on mining and milling operations.

SITUATION

The mining camp of Tinton is on Nigger Hill in the northwest corner of Lawrence County, S. Dak., almost on the Wyoming line, at an altitude of about 5,900 feet. It is 31 miles by road west of Deadwood, S. Dak.

TOPOGRAPHY

The area immediately surrounding Tinton is mountainous and characterized by a series of irregular ridges and valleys. The highest point is Cement Ridge, at the southeast rim of Nigger Hill, which reaches an altitude of 6,600 feet. The lowest valleys are at an altitude of about 4,500 feet. The area is drained mainly by tributaries of the Belle Fourche system, which flow in a northerly direction.

CLIMATE

The nearest station of the United States Weather Bureau is at Spearfish S. Dak., 12 miles northeast of Tinton, at an elevation of 3,647 feet.

Climatic data recorded at Spearfish over a period of 34 years are assembled in table 1:3/

3/ U. S. Weather Bureau, Climatic Summary of the United States, 1933.

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TABLE 1. - Climatic data at Spearfish, S. Dak.

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
emperature:													
Average.....	25.0	25.6	33.4	45.0	53.6	62.9	70.0	68.6	59.9	48.8	36.7	26.9	46.4
Average Maximum	35.4	36.0	44.5	56.7	65.4	75.2	82.8	82.2	73.1	60.8	47.5	38.2	58.2
Average Minimum	14.5	15.1	22.2	33.2	41.8	50.6	57.2	55.0	46.7	36.8	25.9	17.5	34.7
Highest.....	79	71	82	90	92	102	104	104	102	95	85	73	104
Lowest.....	-31	-29	-18	-8	11	25	35	33	15	-12	-15	-30	-31
recipitation(in.):													
Average.....	0.74	0.79	1.48	2.31	3.40	3.70	2.25	1.77	1.55	1.51	0.85	0.77	21.12
Highest.....	2.25	3.57	7.40	5.56	10.14	9.10	7.84	4.40	6.18	4.03	4.50	2.38	37.03
Lowest.....	T	0.10	0.08	0.27	0.90	0.33	0.20	0.05	0	T	0	T	11.55
owfall (inches):													
Average.....	8.5	7.7	12.4	9.8	2.1	T	0	0	0.6	4.9	8.0	8.0	62.0

HISTORY

The first mining done in the Tinton area was placer mining for gold in the reams with headwaters on the slopes of Nigger Hill. The identification of stream in with the gold led to the development of pegmatite dikes containing cassiterite, ntalite, amblygonite, spodumene, and associated minerals.

GEOLOGY

The general geology of the Tinton area has been described by Darton and ith.[4] A more recent study of the pegmatites of Nigger Hill has been made by ess and Bryan.[5] The Tantalum Hill (a part of Nigger Hill) pegmatite is the rgest in the area. It is included in the Giant and Volney claims of the Black lls Tin Co.

TOWNSITE

In July 1938 about 25 families were living at Tinton; there were three vacant uses. Other buildings at the camp include a community building, a school, a st office, and a filling station.

Water for camp use is pumped to an 8- by 10-foot pressure tank above the wnsite.

The buildings are lighted by electricity supplied by a small gasoline-driven nerating unit.

All employees are furnished house, lights, and water.

4/ Darton, N. H., and Smith, W. S. T., Sundance Folio: Geological Survey Geol. Atlas 127, 1905.

5/ Hess, Frank L., and Bryan, Barnabas, Jr., The Pegmatites at Tinton, S. Dak. Bureau of Mines Rept. of Investigations 3404, 1938, 19 pp.

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TANTALITE AND ASSOCIATED MINERALS

Mining

In 1927 a road grader uncovered the first tantalite found in the Tinton area. Prospecting by cuts followed. During that year a mill was built equipped with crusher, rolls, and coarse- and fine-concentrating tables. About 12 tons of tantalum concentrates were produced in 7 months in 1928, following which a gasoline shovel was installed at the mine, first for stripping and later for mining. The ore was hand-sorted. Shovel mining was discontinued after a few months. As a result of mining operations, test-pitting, and trenching it was found that the tantalite is in four nearly parallel zones that trend in a northerly direction. The tantalite zones occupy the south-central part of the Tantalum Hill pegmatite. They are numbered consecutively from west to east, as shown in figure 1. The Tantalum Hill shaft, a 2-compartment incline, is on the footwall of No. 1 zone near the northern ends of zones 1, 2, and 3 and about 100 feet west of the center of zone 4.

No. 1 zone was mined for tantalite by a gasoline shovel down to a level approximately 15 feet above the elevation of the shaft collar. The operation closed on January 26, 1929. In 1935 and thereafter the same zone was mined for amblygonite, and the original cut has been deepened to a level 4 or 5 feet below the shaft collar.

Prior to April 1, 1937, the amblygonite in No. 1 zone was mined by the Black Hills Tin Co. About 8 carloads, averaging 45 tons each, were shipped to the Foote Mineral Co. at Philadelphia. The lithia (Li_2O) content of the shipments averaged 8.1 percent. Payment was made on the basis of $37.50 for 8 percent lithia, with a bonus of $1 for each 1/10 percent of lithia over 8 percent.

Since April 1, 1937, the Fansteel Mining Corporation of Chicago, Ill., has been in charge of tantalum operations in No. 1 zone. All amblygonite mined since that date was stock-piled; in June 1938 a 41-ton carload of amblygonite was shipped from the stock pile to the Maywood Chemical Works at Maywood, N. J. It assayed about 8 percent lithia and was paid for on the above basis.

About 10 feet of spud-quartz, a fine-grained intergrowth of spodumene and quartz, separate No. 1 and No. 2 tantalite zones.

In the summer of 1937, No. 2 and No. 3 zones were mined in a cut just north of the Tantalum Hill shaft where the two zones intersect. The cut was about 100 feet in length and 20 feet in width and averaged about 6 feet in depth. The tantalum ore was broken down by means of vertical holes drilled with a jackhammer. The bottom of the pit was on the same elevation as the floor of the sorting room, which adjoins the shaft house, but the ore was dumped directly into the mill-ore bin without sorting; it assayed 2.4 to 3 pounds of tantalum per ton.

The tantalite in No. 4 zone occurs in necronite, or fetid microcline. The surface mining of an ore body in that zone was completed in February 193

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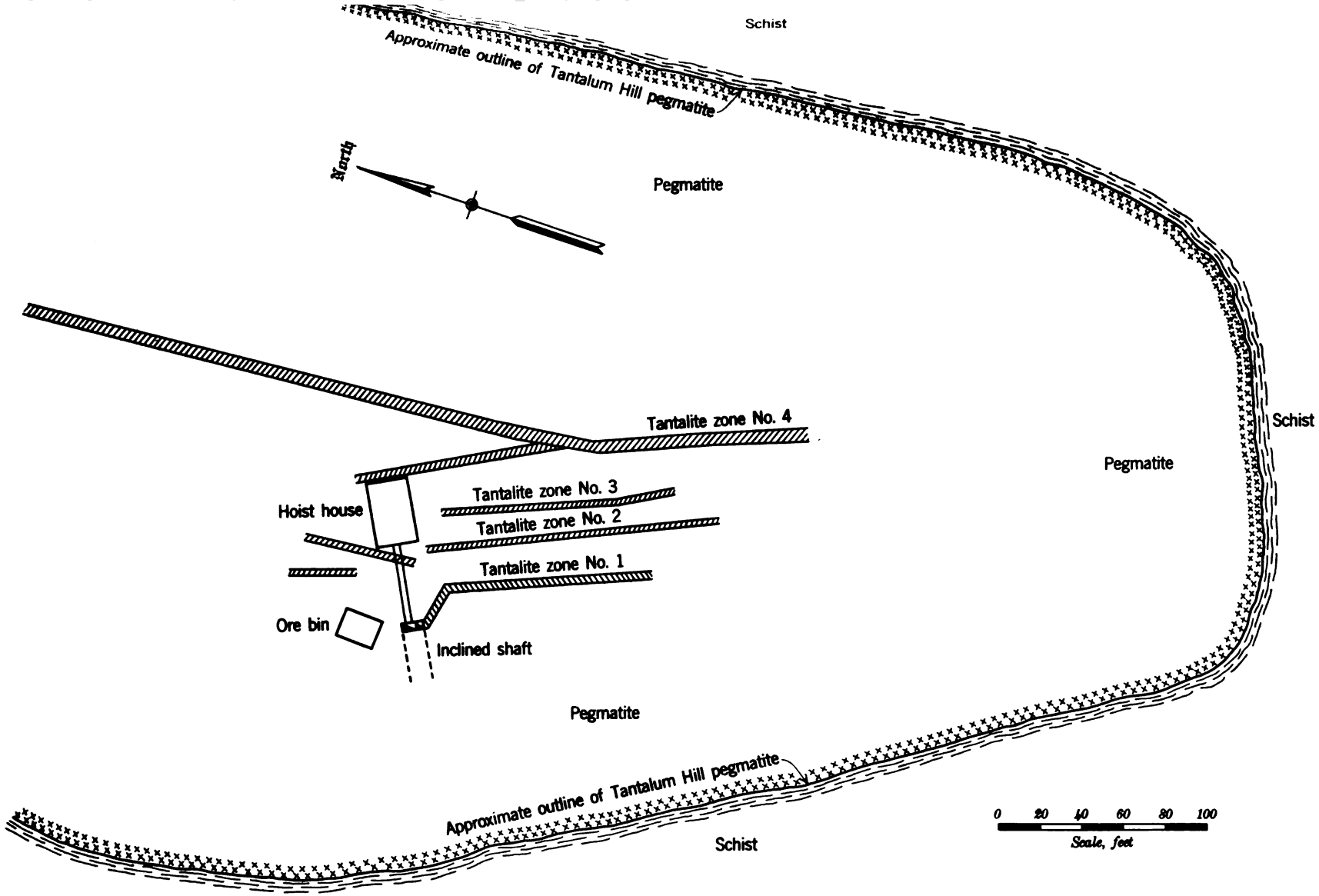

Figure 1.—Map showing location of tantalite zones in Tantalum Hill pegmatite (after A. I. Johnson).

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The operation was carried out as follows: A surface trench was cut easterly a distance of 20 feet to intersect the sheeting zone of quartz and microcline. Then a pit was opened along the strike of the deposit. The pit when abandoned was about 50 feet long, 15 feet wide, and 15 feet deep. The material mined assayed 2.5 pounds of tantalum per ton before sorting. The floor of the pit was at the same elevation as the track on the sorting floor of the hoist house. The sides of the pit were extended by glory-hole methods. About three vertical jackhammer holes 6 feet deep were drilled per day. Each hole was loaded with three sticks of 40-percent-strength dynamite. The round broke 20 to 40 tons of ore, which was shoveled into a 1-ton mine car in the pit. A man trammed the loaded car about 50 feet and dumped it into a small wooden chute in the sorting house. The chute gate was of the conventional board type. Coarse waste was sorted out at the chute gate and thrown into a 1-ton car parked near the chute. The ore was allowed to drop into another 1-ton car under the chute. About half of the material was sorted out for waste; it was trammed about 20 feet and dumped into a 40-ton waste bin. The ore was dumped into another 40-ton bin next to the waste bin. A 2-ton truck loaded to 2-1/2 tons hauled the waste about 300 feet to a dump, unless it consisted mainly of spud-quartz, in which case it was hauled about 1,000 feet and stock-piled along the camp road. The same truck hauled the ore about half a mile to the mill; the first 500 feet of haul was upgrade, the rest downgrade.

It is planned to mine this zone from the 60-foot mine level to the floor of the present surface cut by means of an open stope about 6 feet wide.

A streak of tantalum ore 4 to 6 feet wide forms a northerly extension of No. 4 tantalite zone. The surface exposure lies between two tin zones about 75 feet above a (Rough & Ready) crosscut but does not appear in the crosscut.

The Tantalum Hill shaft was being sunk at the time that No. 2 and No. 3 zones were mined. It is a two-compartment incline dipping 55° W. and follows the footwall of No. 1 tantalite zone. The hoisting compartment is 5 by 5 feet and the manway is 4 hy 5 feet, inside dimensions. In July 1938 the shaft was 60 feet deep, measured on the incline. Hoisting is done by a geared hoist driven by a 35-horsepower motor. A 900-pound self-dumping bucket is used; the rope is 7/8 inch. The bucket dumps into a 1-ton mine car. The track is on the level of the sorting floor, which is 28 feet vertically above the shaft collar. The hoist is 12 feet above the sorting floor.

In the summer of 1938, No. 2 tantalite zone was being mined south of the Tantalum Hill shaft. A glory-hole method was used. Mining was done by one miner working an 8-hour shift. About six 6-foot jackhammer holes were drilled per day along the east wall of No. 2 zone. Six sticks of 40-percent-strength gelatin dynamite were used in each hole. The round usually broke 72 to 80 tons. Large boulders resulting from the blast were broken by blockholing and sledging. The broken ore ran into the top of No. 1 raise, which had been driven up 40 feet at 50° from the 60-foot level. There was a chute at the bottom of the raise provided with board gates, through which the ore was loaded into a 900-pound hoisting bucket on a truck. The bucket was trammed 50 feet to the shaft bottom over a track of 12-pound rails and 24-inch gage. The drift on the 60-foot level is 7 feet high and 8 feet wide; it is untimbered.

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The bucket was hoisted up the incline and dumped into a 1-ton car, as previously described. (See p. 5.) The hoistman trammed the car about 30 feet to the sorting room, which adjoins the hoist house. The 72 to 80 tons of ore broken per day yielded about 35 tons of mill ore containing about 5 pounds of tantalum concentrate per ton.

Ore and waste were trucked from the bins.

A second raise 50 feet south of No. 1 raise broke through to the surface about the end of July 1938. It had been driven up 50 feet from the 60-foot level at 60°; the rock section was 5 by 6 feet. It is planned to construct a grizzly at the top of the raise and break down the ore over the raise in a manner similar to that described for No. 1 raise. A third raise is to be driven next between the Tantalum Hill shaft and No. 1 raise.

Compressed air for drilling was furnished by a 6-1/2- by 5-1/2-inch V-type compressor in the mill building, driven by a 50-horsepower motor. The air was delivered at a pressure of 110 pounds per square inch through a 3-inch pipe to a 3-1/2- by 10-foot receiver in the mill, then through a 2-inch line to a 4- by 15-foot receiver at the mine. The distance from the mine to the mill is about half a mile. Drilling in the mine is done wet by means of a small pressure tank. Surface drilling is dry. One-inch hollow hexagon steel is used.

Amblygonite is present in pockets in the cut on No. 2 tantalite zone. When found, it is mined separately under contract; the company pays $16 per ton for the sorted amblygonite.

A zone of amblygonite parallel to the tantalite zones and about 200 feet east of No. 2 tantalite zone has been exposed by 150 feet of trenches. About 40 tons of amblygonite have been mined from a few pockets in the zone.

Considerable spud-quartz has been mined as a byproduct of tantalite and amblygonite mining. Spud-quartz sorted out of the ore is not thrown over the waste dump but is stock-piled along the camp road. The material stored contains about 3 percent Li_2O. The Black Hills Tin Co. is experimenting to develop a method for the economical recovery of spodumene or lithia from spud-quartz. The experimental work that was being done in July 1938 is described on page 13.

The spud-quartz mined near the center of the Tantalum Hill dike contains about 50 percent spodumene; some of that mined near the ends of the dike contains only 25 percent spodumene. The stock piles contain about 50 percent spodumene.

Other minerals associated with tantalite or amblygonite are dumped as waste. The microcline and soda spar are mixed so intimately with quartz that a product of either spar would contain too much free silica to be

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marketable. The iron content also would be too high. The feldspar analyses in table 2 were made for the company on July 13, 1938:

TABLE 2. - Analyses of Tinton feldspars

	South end of deposit, percent 1/	Middle of deposit, percent 2/	North end of deposit, percent 3/
SiO_2.....	72.9	62.8	69.3
Al_2O_3.....	17.1	19.7	17.9
Fe_2O_3.....	.168	.10	.29
CaO.....	.5	1.5	1.6
MgO.....	Not determined	-	-
Na_2O.....	6.1	2.2	7.6
K_2O.....	1.9	12.7	2.1
Loss on ignition...	1.4	.7	1.2
	100.068	99.7	99.99

1/ Dump material from tantalum cut on No. 2 zone taken from behind hoist house.
2/ Necronite from big cut on No. 4 tantalum zone.
3/ Soda spar from road cut on No. 4 tantalum zone.

Considerable mica could be sorted out but cannot be marketed at a profit because of high transportation costs; it is thrown for waste.

In the south end of the mine two pockets of beryl yielded about 550 pounds. The beryl was sacked.

The distribution of the cost of daily mine labor is shown in table 3.

TABLE 3. - Direct mine labor

Number	Occupation	Rate	Cost per day
2	Miners	$4.00	$8.00
2	Chute pullers	3.00	6.00
4	Ore sorters	3.00	12.00
2	Hoist men	3.50	7.00
1	Truck driver	3.00	3.00
1/2	Blacksmith	4.50	2.25
11-1/2			38.25

Timber for mine sets is cut locally. Sawed lumber costs $20 per thousand board feet delivered at Tinton.

Milling tantalite ore

In July 1938 the Fansteel Metallurgical Corporation was milling about 32 tons of tantalite ore per day in the 250-ton mill building of the Black Hills Tin Co. Trucks hauled the tantalite ore from the mine to the mill. The flow

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sheet of the mill is shown in figure 2. The load of 2-1/2 tons is dumped into a chute at the top of the mill building. The chute delivers the ore to a gyratory crusher driven by a 15-horsepower motor. The product of the gyratory crusher, minus 2 inches in size, is conveyed about 40 feet up a 10° slope on a 20-inch belt and discharged onto a vibrating screen. The screen is 5 by 5 feet with 1-inch openings; it is driven by a 1/2-horsepower motor. The screen oversize is crushed to 1/4 inch by a cone crusher and joins the undersize in a 10-ton bin. The crusher is driven by a 30-horsepower motor. One man operates the crushing plant; he works on the day shift.

From the 10-ton bin the fine ore is trammed about 50 feet in a 1-ton mine car and dumped into a 25-ton bin at the head of the concentrating section. This section is operated two shifts per day by one man on each shift; a roustabout on the day shift completes the mill crew of four men. A rack-and-pinion gate at the bottom of the 25-ton bin delivers the fine ore to an oscillating feeder of the scoop type, which feeds it to the boot of a bucket elevator. The ore is raised 30 feet to a 1/2-inch vibrating screen. The oversize from the screen passes through a small set of rolls and is then returned to the bucket elevator. The screen undersize passes to a 1/8-inch vibrating screen, the oversize from which is delivered to the rolls. The undersize from the 1/8-inch screen passes to a 20-mesh vibrating screen, the oversize from which is caught in a hopper and the undersize from which passes to a 30-mesh vibrating screen.

The oversize and undersize products from the last screen are allowed to accumulate in bins of 4 tons capacity each. About 12 tons of plus-20-mesh material, about 2-1/2 tons of plus-30-mesh material, and about 1-1/2 tons of minus-30-mesh material are made in a shift. Each product is given the same treatment on concentrating tables. The tables make a tail that is discharged, a concentrate, and a middling. The concentrates are dried in an oil-fired drier and then shoveled into a nest of 2- by 2-foot vibrating screens driven by a 1/2-horsepower motor. The middlings are rerun on a clean-up table, the resulting concentrate being dried and sacked and the tails discharged. Screen sizes used for the concentrates are 1/8-inch, 20-mesh, 30-mesh, 48-mesh and 60-mesh. Inasmuch as all the material reaching the tables has already passed through an 1/8-inch screen, there should be no concentrates on the 1/8-inch screen of the set. The insignificant amount that sometimes appears is returned to the rolls. The five other products made by the set of screens - the plus-20-mesh, plus-30-mesh, plus-48-mesh, plus-60-mesh, and minus-60-mesh products - are treated separately on a concentrating table. The concentrates made are dried in pans and sacked. The middlings are rerun on the table, and the resulting concentrates are added to the other concentrates. The tails, including those made by re-treating the middlings, are discharged into Mallory Gulch. The tailings are settled in a series of three brush dams and a large earth dam about half a mile down the gulch.

The concentrates are sampled by mixing the various sizes and then coning and quartering down to 3 pounds. The final sample is divided into three parts - one for the Black Hills Tin Co., one for the Fansteel Metallurgical Corporation, and one for reserve in the Tinton office.

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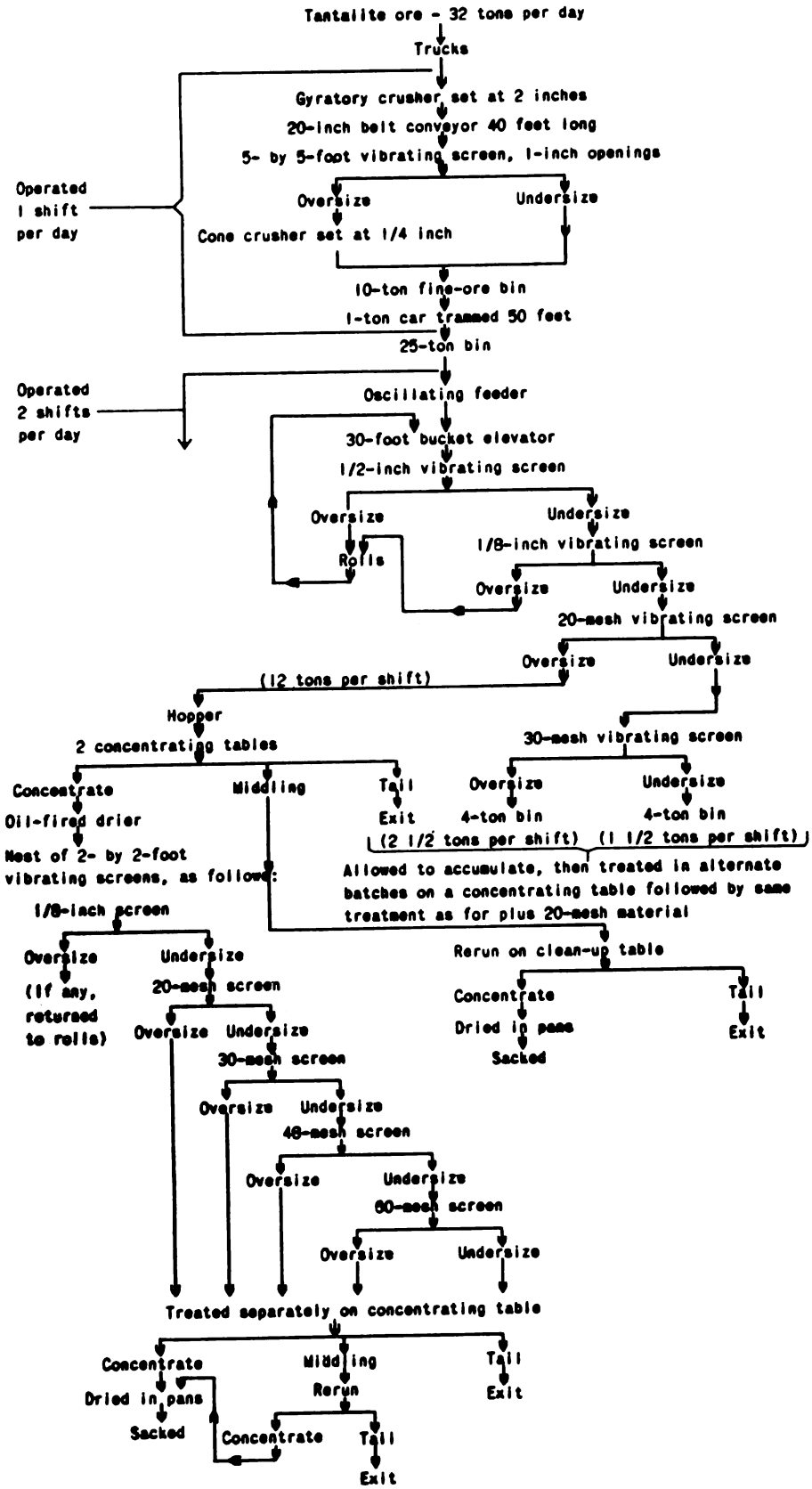

Figure 2.- Flow sheet of tantalite mill of Fansteel Mining Corporation at Tinton.

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The production of tantalite concentrate from Tantalum Hill is recorded by Johnson[6/] as follows:

Year	Pounds
1928.....	17,263
1929.....	8,962
March 1937 to August 1938.	17,279

The mill uses about 20,000 gallons of new water per day in addition to a small quantity of reclaimed water. Water for milling is pumped from a sump in Mallory Gulch about 3/4 mile below the mill. A triplex pump driven by a 30-horsepower motor lifts the water into a 12,000-gallon storage tank above the mill; the pumping head is about 500 feet. The pump usually runs 5 hours a day.

The distribution of the cost of daily mill labor is shown in table 4.

TABLE 4. - Direct mill labor

Number	Occupation	Rate	Cost per day
2	Table men.....	$3.00	$6.00
1	Crusher man....	3.00	3.00
1	Roustabout.....	3.00	3.00
1/2	Mechanic.....	4.00	2.00
1/2	Electrician....	4.00	2.00
5			16.00

Power Plant

The power plant for the mine and mill is housed in the mill building. It comprises two independent power units, one being operated while the other is held in reserve. In each unit a 90-kilowatt electric generator is driven by a Diesel engine by means of a 17-inch leather belt. By means of transformers controlled on the switchboard at the generator, the generated voltage of 480 is cut down to 440, 220, and 110 volts for use in the motors at the mine and mill. The current is 3-phase 60-cycle.

The Diesel engine that drives the generator is a single-cylinder, 4-cycle, 150-horsepower engine that makes 164 revolutions per minute. It consumes 5 gallons of heavy distillate per hour. The distillate costs 6-1/2 cents per gallon; it is stored in a 4,000-gallon tank. The engine uses 2-1/2 gallons of lubricating oil in 16 hours, most of which is reclaimed. The oil costs 54-1/2 cents per gallon. In addition, four pints of a special Diesel lubricating oil are used in two shifts.

Direct labor charged to the power plant includes two operators - one on each of the two shifts worked - and half the services of a blacksmith, half the services of a mechanic, and half the services of an electrician during the day shift.

6/ Johnson, A. I., Tantalum from the Black Hills: Eng. and Min. Jour., vol. 139, 1938, pp. 39-42.

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The distribution of daily power-plant labor is shown in table 5.

TABLE 5. - Direct power-plant labor

Number	Occupation	Rate	Cost per day
2	Operators.....	$3.50	$7.00
1/2	Blacksmith.....	4.50	2.25
1/2	Mechanic.....	4.00	2.00
1/2	Electrician.....	4.00	2.00
3-1/2			13.25

Costs

The distribution of the costs of mining and milling tantalite ore and of producing amblygonite are shown in tables 6 to 12, inclusive.

TABLE 6. - Tantalite mining costs per ton of ore broken.

Period covered: June 16 to June 30, 1938.

Sorted tantalite ore hauled to mill.....	tons	387.0
Sorted waste.....	do.	305.6
Tantalite ore broken.....	do.	692.6

	Underground costs per ton of tantalite ore broken					
	Labor	Supervision and office	Power	Explosives	Supplies	Tot
Development.....	$0.034	-	$0.051	$0.024	$0.020	$0.1
Mining.....	.013	-	.095	.018	.002	.1
Underground transportation.....	1/ .008	-	-	-	-	.3
	2/ .315	-	-	-	-	
General underground expense....	2/ .002	.099	-	-	-	.1
Surface expense directly applicable to underground operation.....	1/ .026	-	-	-	2/ .003	.0
	2/ .051	-	-	-		
Total underground..	.449	.099	.146	.042	.025	.7
Surface sorting at mine.....	.189	-	-	-	-	.1
Trucking to mill...	.055	-	-	-	.015	.0
Total direct mining	.693	.099	.146	.042	.040	1.0

1/ Development.
2/ Mining.

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TABLE 7. - Tantalite mining costs per ton of sorted ore.

Period covered, June 16 to June 30, 1938.

Sorted tantalite ore hauled to mill.....	tons	387.0
Sorted waste.....	do.	305.6
Tantalite ore broken.....	do.	692.6

	Underground costs per ton of sorted tantalite ore					
	Labor	Supervision and office	Power	Explosives	Supplies	Total
Development.....	$0.061	-	$0.092	$0.043	$0.036	$0.232
Mining.....	.024	-	.170	.032	.004	.230
Underground transportation.....	1/ .014 2/ .562	- -	- -	- -	- -	.576
General underground expense.....	2/ .003	.178	-	-	-	.181
Surface expense directly applicable to underground operation.....	1/ .047 2/ .091	- -	- -	- -	2/ .005	.143
Total underground....	.802	.178	.262	.075	.045	1.362
Surface sorting at mine.....	.339	-	-	-	-	.339
Trucking to mill.....	.099	-	-	-	.027	.126
Total direct mining..	1.240	.178	.262	.075	.072	1.827

1/ Development.
2/ Mining.

TABLE 8. - Tantalite milling costs.

Period covered: June 16 to June 30, 1938.

Tantalite ore milled.....	tons	371
Tantalite concentrate produced.....	pounds	1,610
Tantalite concentrates on hand June 30, 1938.....	do.	3,096

	Milling costs per ton of tantalite ore milled						
	Operating labor	Supervision and office	Power	Supplies	Repairs Labor	Repairs Supplies	Total
Coarse crushing	$0.100	-	-	-	-	-	$0.100
Fine crushing, tabling.....	.182	-	-	$0.010	-	-	.192
Cleaning concentrates.....	.051	-	-	.046	-	-	.097
Pumping.....	.053	-	-	-	-	-	.053
Tramming from crushing unit to concentrating unit.....	.031	-	-	-	-	-	.031
General.....	-	$0.185	$0.207	-	$0.100	$0.012	.504
Total direct milling.....	.417	.185	.207	.056	.100	.012	.977

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TABLE 9. - Power-plant costs

Period covered: June 16 to June 30, 1938.
Power produced: 8,350 kw.-hr. at 2.13 cents per kw.-hr.

	Operating labor	Supplies			Total
		Fuel oil 1/	Lubricating oils 2/	Rags	
Power costs per ton of sorted tantalite ore (387 tons):					
Mine development.....	$0.047	$0.038	$0.007	-	$0.092
Mine operation.....	.086	.071	.013	-	.170
Total power for mining	.133	.109	.020	-	.262
Power costs per ton of tantalite ore milled (371 tons):					
Milling.....	.104	.086	.016	$0.001	.207
Power costs per ton of ore mined and milled:					
Total direct power....	.237	.195	.036	.001	.469

1/ 1,168 gallons of distillate.
2/ 30 gallons of Atlantic red oil..... $9.60
52 pints of Nonpareil oil..... 3.97
Total lubricating oils..... 13.57

TABLE 10. - Operating costs per ton of tantalite ore milled and per pound of tantalite concentrate produced

Period covered: June 16 to June 30, 1938.
Ore milled during the period..... tons 371.
Concentrate produced..... pounds 1,610.

	Cost per ton of ore milled		Cost per pound of tantalite concentrate produced	
Mining:				
Development.....	$0.305		$0.070	
Stoping.....	.929		.214	
Sorting.....	.354		.082	
Trucking to mill.....	.131		.030	
Supervision and office	.186		.043	
Total mining.....		$1.905		$0.439
Milling:				
Operating.....	.792		.182	
Supervision and office	.185		.043	
Total milling.....		.977		.225
Total mining and milling...		2.882		.664

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TABLE 11. - Lighting-plant costs per ton of sorted tantalite ore (387 tons)

Period covered: June 16 to June 30, 1938.

	Operating labor	Repairs	Total
Direct lighting cost.....	$0.019	$0.006	$0.025

TABLE 12. - Cost per ton of producing amblygonite.

Period covered: June 16 to June 30, 1938.
Amblygonite produced.....tons 3.489
Amblygonite on hand June 30, 1938..... do 14.495

	Operating labor	Supplies	Total
Mining.....	$16.00	$0.55	$16.55
Cobbing.....	3.87	-	3.87
Total production cost...	19.87	.55	20.42

EXPERIMENTAL WORK WITH "SPUD-QUARTZ"

The Black Hills Tin Co. has been conducting experiments at Tinton with a view to developing a process for the economical production of spodumene concentrates and lithium chloride from spud-quartz. The spud-quartz treated is a very fine-grained intergrowth of spodumene and quartz in about equal amounts without significant quantities of other minerals; it usually contains about 3 percent lithia (Li_2O). The following analysis of spud-quartz from the main glory hole on Tantalum Hill was supplied by the company:

	Percent
SiO_2.....	75.9
Al_2O_3.....	17.53
Fe_2O_3.....	.017
CaO.....	.05
MgO.....	.12
Li_2O.....	3.50
Na_2O.....	1.70
K_2O.....	Trace
H_2O.....	.22
Loss on ignition..	.73
Total.....	99.767

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The material used in the test work was obtained from stock piles along the camp road, where it has accumulated as a byproduct of the mining of tantalite and amblygonite on Tantalum Hill.

In July 1938 experimental work was being conducted along three lines:

1. The separation of spodumene from quartz by decrepitation of the spodumene, followed by gentle grinding and air sizing. The procedure followed in a general way the method described by Fraas and Ralston.7/

2. The treatment of spodumene for the production of lithium chloride. The method involves the volatilization and subsequent condensation of lithium chloride; it was patterned after experiments described by Fraas and Ralston.8/

3. The separation of spodumene from quartz by the flotation of the spodumene.

The separation of spodumene from quartz by decrepitation of the spodumene was conducted as follows: Spud-quartz from the stock piles was hauled by truck to the mill and dumped into a gyratory crusher. The minus-2-inch product of the gyratory crusher passed to a cone crusher, which crushed it to minus-1/2 inch. The crushed material was shoveled into a 1-1/2- by 4-foot rotary furnace in batches of about 200 pounds. The furnace was kept at a temperature of 1,050° C. by means of a distillate burner at the intake end and was rotated at a speed of 2-1/2 revolutions per minute. The charge was heated for an hour and then allowed to cool. The cooled material was shoveled into a 1-1/2- by 1-1/2-foot rubber-lined pebble mill containing rubber cubes for gentle grinding. The ground material was delivered by a spiral feeder to a vertical 8-inch sheet-iron pipe 8 feet long, which served as a sorting column. A blower delivered air to the column near the bottom through a 6-inch pipe that terminated in a 3-inch nozzle. The quartz in the feed settled out below the nozzle. The more finely pulverized spodumene was carried up by the air current into a 4- by 4-foot settling chamber. The air rose through the chamber along the sides and then passed through a series of baffles and out. The spodumene concentrate made by this method contains about 6 percent lithia; it is worth $35 per ton in eastern markets.

The following assays and screen analyses of spodumene concentrates were supplied by the company.

TABLE 13. - Screen analyses of concentrates produced by decrepitation of spodumene

Sample No. 1. - Concentrate assayed 5.32 percent lithia

Screen size	Percent	Spodumene content (estimated), percent
Plus 100 mesh.....	47.0	40
Minus 100 mesh, plus 200 mesh	37.6	80
Minus 200 mesh.....	15.5	80
	100.1	

7/ Fraas, Foster, and Ralston, Oliver C., Beneficiation of Spodumene by Decrepitation: Bureau of Mines Rept. of Investigations 3336, 1937. 13 pp.

8/ Fraas, Foster, and Ralston, Oliver C., Chloride Volatilization of Lithium from Spodumene; Bureau of Mines Rept. of Investigations 3344, 1937, 11 pp.

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TABLE 13. - Screen analyses of concentrates produced by decrepitation of spodumene (Continued)

Sample No. 2. - Concentrate assayed 5.18 percent lithia

Screen size	Percent	Spodumene content (estimated), percent
Plus 100 mesh.....	22.6	30
Minus 100 mesh, plus 200 mesh.	56.7	90
Minus 200 mesh.....	20.7	90
	100.0	

Sample No. 3. - Concentrate assayed 5.18 percent lithia

Screen size	Percent	Spodumene content (estimated), percent
Plus 100 mesh.....	24.5	50
Minus 100 mesh, plus 200 mesh.	53.2	75
Minus 200 mesh.....	22.38	75
	100.08	

Sample No. 4. - Concentrate assayed 6.40 percent lithia

Screen size	Percent	Spodumene content (estimated), percent
Plus 100 mesh.....	5.5	66
Minus 100 mesh, plus 200 mesh.	48.2	90
Minus 200 mesh.....	46.3	75
	100.0	

The treatment of spodumene for the production of lithium chloride was carried out in the same furnace that was used for the decrepitation treatment (see p. 14). The charge consisted of:

	Pounds
Spud-quartz.....	100
Limestone.....	100
Calcium chloride...	17

The ingredients were mixed and ground to minus 65 mesh before being put into the furnace, which was preheated to 1,050° C. The furnace was rotated at a speed of 2-1/2 revolutions per minute, and the temperature of the charge was maintained at 1,050° C. for 1-1/2 hours. The evolved gases passed into a horizontal sheet-iron pipe 28 inches in diameter. The pipe was divided into five sections or "kitchens," each 2 feet long, by means of vertical baffle plates that left openings for the gases to pass alternately above and below the plates. Lithium chloride formed in the furnace; it volatilized and passed into the kitchens, where it condensed. It was removed through small doors in the side of the kitchens. The other furnace gases passed through the

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kitchens and up a stack. The last run that was made in July 1938 yielded half a pound of lithium chloride of approximately 50-percent purity. The spud-quartz used assayed about 3 percent lithia, so that the charge contained 3 pounds of Li_2O. The clinker was used for cement rock. From time to time the treatment has been modified, resulting in improved extraction.

The flotation experiments were conducted as follows: Spud-quartz from the stock piles was crushed to minus 1/2 inch in the same manner as for the decrepitation treatment. A 400-pound charge was ground in a 3- by 3-foot batch ball mill lined with jasper. Pebbles of spud-quartz were used for grinding. The ground product was put over a 1/2-inch screen, and the oversize was saved to be added to the next charge. The screen undersize dropped into a small bin, from which it was shoveled out later and fed to an 18- by 30-inch 65-mesh vibrating screen. The screen oversize was saved for the next charge. The undersize was stored in a hopper, from which it was fed in batches to a four-cell Ruth flotation machine. The total weight of the flotation charge was 1,800 pounds. Enough water was added just ahead of the first cell to produce a pulp with 25 percent solids. The following flotation reagents were added with the water:

	Pounds per ton
Emulsol, K480.	1
Oleic acid....	2

The flotation machine made a shipping concentrate in each cell. The concentrates were allowed to settle in a bin, after which they were dried and sacked. They contained about 5 percent lithia. Flotation tails were run to waste.

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